Chapter 1

Basic Approach to Pediatric Trauma

Approximately 75% of children admitted to deployed level-three facilities since 2001 have been victims of trauma, and 75% of that trauma was penetrating, caused by myriad mechanisms.[1] Although extremity wounds, including traumatic amputations, were the most frequent injuries reported, major sources of mortality in the resuscitation phase were head injury, penetrating thoracic wounds, and burns. Previous epidemiologic reviews have found significantly higher mortality rates for infants, younger children, and females (see Further Reading). Independent predictors of mortality include pH less than 7.1, Glasgow Coma Scale (GCS) score less than 4 on presentation, or the need for more than one unit of packed red blood cells or fresh frozen plasma.

Triage for children is similar to that for adults; it is a system used to prioritize treatment, taking into account the extent of the trauma (ie, polytrauma or a single injury), type of trauma (ie, blunt or penetrating), and the severity of the illness or injury. The goal is the same for children as for adults: to save as many patients as possible with the resources available.

Anatomical and Physiological Considerations

- General differences
  - Abnormal general appearance is indicative of a serious illness or injury
  - Normal responses differ by age (ie, developmental stages)
  - Vital signs are based on age
  - Bradypnea and bradycardia are both ominous
  - Children have a larger relative surface area for a given weight than adults
    - This puts them at higher risk for hypothermia
      - Hypothermia can increase oxygen requirements
      - Obtain rectal temperature; monitor and maintain temperature at 36.5°C–37.5°C

      - Hypothermia is associated with apnea and bradycardia
      - The head is a major source of heat loss; mitigate heat loss by covering the head with a hat or cap
    - Because of their larger surface-area-to-weight ratio, children also sustain greater insensible water loss and have different fluid requirements than adults (see Chapter 22, Basic Fluid and Electrolytes)
  - Children have a conical airway; the cricoid is the narrowest portion of the airway
  - The pediatric skull has expandable sutures until 18–24 months of age
  - Children's short, fat necks make assessing for tracheal deviation or jugular venous distention more difficult than in adults
  - Cervical spine fractures are less common than ligamentous injury
    - Injury is more likely to be at a higher cervical level in children than in adults
    - Spinal cord injury without radiographic abnormality can be seen in up to 50% of children with spinal cord injuries
  - Children's pliable ribs make fractures less likely; transmitted energy is more likely to cause pulmonary contusion
  - Tension pneumothorax is more likely in children than in adults due to the mobile contents of the mediastinum
  - Solid abdominal organs are more susceptible to injury because of their anterior placement, children's less-developed abdominal walls, and subcutaneous fat
  - Fractures of long bones with active growth plates can result in length discrepancies
  - Medications are all dosed as milligrams per kilogram per dose. Use a Broselow tape for emergency medication dosing, and use a published reference to confirm all other pediatric drug doses (eg, *The Harriet Lane Handbook*; see also the comprehensive equipment table inside the front cover)
  - Psychological impact
    - Very young children may regress in response to pain or

stress, or as perceived threats enter their environment
    - Involving a parent may help in calming the child and acquiring a history
- Neonates and young infants
  - This age group is at increased risk for sepsis due to decreased white blood cell function and count, decreased antibody synthesis, and decreased inflammatory response
  - Neonates are more sensitive to drugs because of their immature blood–brain barrier
  - Hypoglycemia is more common in this age group because of their smaller glycogen stores
  - Neonates' smaller functional residual capacity makes desaturation more common
  - Apnea and bradycardia occur in response to decreased partial pressure of oxygen and increased carbon dioxide in young infants
  - Hypocalcemia will result in hypotension; intravenous (IV) calcium is an inotrope in young infants

Assessment

- Life-threatening conditions should be treated as soon as they are identified
- Primary survey (should take no more than 5–10 min)
  - Start with a 30-second pediatric advanced life support (PALS) rapid cardiopulmonary assessment
  - **Airway** (the most common cause of cardiac arrest in children is respiratory failure; support the airway first)
    - Is the child's airway clear and maintainable, or does the patient require intubation?
    - Maintain and control open airway
    - The child's head should be placed in the sniffing position
      - Use jaw thrust if injury to the cervical spine is a concern
      - A child's relatively large tongue and prominent occiput cause the head to flex forward and potentially obstruct the pediatric airway
      - Position and suction the airway as necessary
        - The larynx is funnel shaped, cephalad, and ante-

rior in the neck
- An infant's trachea is about 5 cm long; a toddler's is about 7 cm long
- Unintentional right mainstem intubation is common in small children

- Consider placing an oropharyngeal (in an unconscious patient) or nasopharyngeal airway
- Intubation is indicated for any of the following:
  - GCS score ≤ 8
  - No gag reflex
  - Prolonged transport
  - If bag-valve mask ventilation is ineffective
  - If sensorium is depressed and hypovolemia or hypotension are present
- Cricothyroidotomy (needle or surgical) is an option for those unable to be bag-mask ventilated or intubated (**NOTE:** surgical cricothyroidotomy should not be performed in children < 12 years of age)

- Rapid sequence intubation
  - Preoxygenate with 100% oxygen by a nonrebreather mask for 2 minutes or 4 vital capacity breaths
  - Administer atropine sulfate (0.02 mg/kg IV) to dry oral secretions and prevent bradycardia from succinylcholine for children < 6 months old
  - Administer an induction agent (Table 1-1)
  - Apply cricoid pressure using the thumb and index finger (5–10 lb pressure on cricoid cartilage)
  - Administer a paralytic: succinylcholine chloride (2 mg/kg for children < 10 kg; 1 mg/kg for children > 10 kg) or rocuronium (0.6–1 mg/kg)
  - Intubate (see comprehensive equipment table inside the front cover)
  - Confirm tube position with capnography or qualitative carbon dioxide first; follow with clinical confirmation (eg, auscultation, chest rise, mist in tube)
  - Release cricoid pressure
  - Secure tube
  - Obtain secondary confirmation with chest radiograph, if available

Table 1-1. Induction Agents for Intubation

Induction Agent	Dose	Characteristics
Etomidate	0.2–0.3 mg/kg IV	Quick onset; ultrashort acting; PALS recommended for head-injured patients
Thiopental	3–5 mg/kg IV	ATLS recommended for normotensive patients
Midazolam	0.1–0.3 mg/kg IV	ATLS recommended for hypotensive patients
Propofol	1–2 mg/kg IV	Avoid using in hemodynamically unstable patients; can worsen hypotension
Ketamine	1–2 mg/kg IV	Limited effect on circulatory system; useful in patients with hemodynamic instability

ATLS: advanced trauma life support
IV: intravenous
PALS: pediatric advanced life support

- **Breathing**
  - Does the patient exhibit increased respiratory rate for age?
    - Infant: > 60 breaths per minute (bpm)
    - Child < 5 years old: > 40 bpm
    - Child > 5 years old through adolescent: > 30 bpm
  - Does the patient exhibit effective air movement (tidal volume)?
    - Decreased air entry is a sign of parenchymal lung disease or poor effort
    - Hypoventilation is common in pediatric trauma
    - Avoid hypercarbia
  - Signs of respiratory distress
    - Retractions (inspiratory)
    - Grunting (expiratory) indicates airway or alveolar collapse
    - Stridor upon inspiration indicates extrathoracic obstruction
    - Wheezing indicates intrathoracic obstruction

- Apply supplemental high-flow oxygen and positive-pressure, bag-valve mask ventilation as necessary
  - Deliver 1 breath every 2–3 seconds
  - Deliver enough volume to generate good chest rise
- Perform needle decompression then insert a chest tube for tension pneumothorax (diagnostic signs and symptoms include hypoxemia, hypotension, and absent breath sounds)

- **Circulation**
  - Observe mental status; the child's level of reactivity and responsiveness is usually a reflection of cerebral perfusion
  - Measure heart rate
  - Feel pulse quality and compare central and peripheral pulses
  - Is there a differential skin temperature? Is the skin cooler distally than it is proximally?
  - Observe capillary refill time; normal is 2 seconds, more than 3 seconds can indicate shock
  - Check pulse pressure
  - Measure blood pressure early
    - A child can be in shock and still have a normal blood pressure
    - Low blood pressure for the child's age indicates decompensated shock
  - Establish vascular access (intraosseous if necessary)
    - Treat shock and hypotension aggressively
    - The preferred isotonic fluid is Ringer's lactate, unless the patient has a head injury (in that case, the preferred fluid is normal saline); bolus volume for a child is 20 mL/kg (repeat once if necessary)
    - Consider early transfusion for hemorrhagic shock
      - Use a 10–15 mL/kg packed red blood cell bolus for blood replacement
      - See Chapter 5, Transfusion Medicine, for further guidance on transfusion therapy
    - Inadequate resuscitation is common; it is most important to control bleeding
    - Diagnose and treat pericardial tamponade (diag-

nostic signs and symptoms include systemic hypotension, muffled heart sounds, and jugular venous distension [Beck triad]), which may be a precursor to pulseless electrical activity)

- **Disability**
  - Quantify GCS score (see modified GCS scores in Chapter 10, Neurosurgery)
  - Does the patient exhibit signs of neurological deficit?
    - Posturing
    - Neurogenic shock (evidenced by hypotension; warm, flushed skin; and spinal shock [absent deep tendon reflexes, hypotonia, flaccid sphincters, priapism])
  - Signs of increased intracranial pressure include headaches, vomiting, altered mental status, and pupillary dilation
  - Does the patient exhibit signs of Cushing triad (irregular respirations, hypertension, and bradycardia)?
  - Minimize secondary brain injury by avoiding or aggressively treating hypotension, hypoxia, hyperthermia, and hyperglycemia
  - Consider administering hypertonic saline (3% sodium chloride); 2–4 mL/kg will decrease intracranial pressure and help restore intravascular volume
- **Exposure** (look for other injuries and be wary of heat loss)
- Adjuncts include cardiorespiratory monitoring, pulse oximetry, end-tidal carbon dioxide and arterial blood gas monitoring, urinalysis, placement of a Foley or gastric catheter, and radiographs (chest, pelvis, lateral cervical spine)

- Secondary survey (should be completed in 10–15 min)
  - Conduct a focused history
  - Perform a detailed head-to-toe examination
  - Identify all injuries requiring surgical intervention
  - Measure urine output using a Foley catheter; normal urine output is at least 1 mL/kg/h
  - Standard adjuncts include complete blood count; coagulation studies; liver function, amylase, and lipase tests; blood type and cross match; computed tomography (CT) scans; complete cervical spine series (including thoracolumbar spine if necessary); and angiography (if necessary and

available)
  - Prioritize management of injuries found in secondary survey
  - Continuously reassess vital signs and airway, breathing, and circulation
- Focused assessment with sonography for trauma (FAST) examination
  - FAST is an alternative to diagnostic peritoneal lavage and CT scan
  - Goals include detecting hemopericardium and hemoperitoneum
  - The examination is positive when intraperitoneal fluid is detected on any of the three abdominal windows, or pericardial fluid is detected on the cardiac window
  - The examination is negative when there is an absence of fluid
  - Performing the FAST examination in the four acoustic windows
    - Pericardial (cardiac)
      - Place the patient in the supine position
      - Place the probe in the midline with the beam directed toward the patient's left shoulder and the probe indicator toward the patient's right shoulder
      - Observe a four-chamber view of the heart
      - A small amount of fluid in the dependent position is normal
      - Fluid present in the nondependent position is abnormal
      - Acute blood will appear anechoic (black); a clot may be echoic
      - Only one hyperechoic line surrounding the heart should be seen
      - Pericardial tamponade can be demonstrated with diastolic collapse of the right atrium or ventricle
    - Perihepatic (right upper quadrant; most likely to have an abnormal finding)
      - Use an intercostal technique (set at the midaxillary line between ribs 8 and 11)
      - Provides views of the liver, right kidney and fluid

in Morison pouch, subphrenic space, right pleural space, and retroperitoneum
    - Free fluid forms spicules or triangulates to follow the path of least resistance
    - Morison pouch pools excess fluid from pelvis and perisplenic areas; use the coronal view and slide caudally until the inferior pole of the kidney is seen. This allows detection of supra- and inframesocolic fluid around the tip of the liver
    - Pleural fluid is accurately detected in 98% of patients
  - Perisplenic (left upper quadrant)
    - Use an intercostal technique; place probe between ribs 9 and 10 or 10 and 11. Technically difficult to get good visualization this way
    - The spleen is located dorsally, so the probe must be placed posteriorly
    - The ideal view contains the left hemidiaphragm, spleen, and left kidney
    - Splenic injury is more difficult to visualize with FAST than with CT scan
  - Pelvic
    - This area is best examined when the bladder is full
    - Perform a complete examination before inserting a Foley catheter
    - Observe both longitudinal and transverse views
    - Place probe just above the pubic symphysis, with the probe indicator pointed toward the patient's head
    - In females, fluid will be present in the pouch of Douglas posterior to the uterus
    - In males, fluid appears in the rectovesicular pouch or cephalad to the bladder
- The presence of fluid or blood is not necessarily an indication for operative intervention

Further Reading

1. Creamer K, Edwards MJ, Shields C, Thompson M, Yu CE, Adelman W. Pediatric wartime admissions to US combat

support hospitals in Afghanistan and Iraq: learning from the first 2,000 admissions. *J Trauma*. 2009;67:762–768.

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3. McGuigan R, Spinella PC, Beekley A, et al. Pediatric trauma: experience of a combat support hospital in Iraq. *J Pediatr Surg*. 2007;42:207–210.
4. Gausche-Hill M, Fuchs S, Yamamoto L, eds. *The Pediatric Emergency Medicine Resource*. Revised 4th ed. Sudbury, Mass: Jones & Bartlett; 2007.
5. Mejia R, ed. *Fundamentals of Pediatric Critical Care Support Course.* Mount Prospect, Ill: Society of Critical Care Medicine; 2008.
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7. Custer JW, Rau RE, Lee CK, eds. *The Harriet Lane Handbook*. 18th ed. New York, NY: Mosby; 2008.